Web-based Decision Support System for Rural Land Use Planning - WebLUP - a Prototype

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ABSTRACT

A mock-up 'Web-based decision support system for rural land use planning – WebLUP' has been developed, using HTML image maps, to assist district-level rural land use managers (rural extension community). It assists the users in their day-to-day decisions on selecting sites for various mandated watershed management schemes by displaying maps and being able to perform useful queries to aid in watershed-based conservation planning decisions. WebLUP, which is a sequel to the PC-based Spatial Decision Support System for rural Land Use Planning (SDSS/LUP) that addresses a single district only, is an attempt to develop a national-level DSS to increase the user base by reducing costs of access to users and data. WebLUP is also intended to provide suggestions and hazard warnings for land use sustainability by combining data from the existing national level survey data sources. The proposed resulting system will be developed after involving and obtaining the informed-opinion from land use policy makers and end-users. The paper also discusses likely future developments of the system for extending the use to the national level.

Keywords: Conservation planning, Decision support system, Geographical information systems, Land use sustainability assessment, Rural land use planning, Watershed management, Web technology

1. BACKGROUND

Rural land use planning in India mainly employs prescriptive planning on a watershed basis through various central/state government-sponsored mandated schemes (e.g. ravine reclamation, integrated rural development programme, etc.) which are financed by state or central governments and implemented by sectoral institutions (top-down) such as Agriculture, Forestry, Irrigation, Rural Development, etc.) to address specific problems and opportunities (Table 1) .

Table 1. Some of the specific items for attention drawn up by the 11th schedule, 73rd and 74th Constitutional Amendment Acts, 1992

Land improvement, implementation of land reforms, land consolidation
Soil conservation
Minor irrigation, water management, watershed development
Social forestry and farm forestry
Roads, culverts, bridges, ferries, waterways
Drinking water
Fuel and fodder
Rural electrification
Adult and non-formal education
Poverty alleviation programs

Rural development planning is also now being decentralised to take account of local conditions and needs. The key level of decentralised planning is the zilla (district). Decision-makers of the district (Civil service officials) are now required to develop and implement integrated development plans and those districts that have independent tax-raising powers can take additional initiatives of their own. However, this task is made the more difficult by the strictly sectoral structure of government activity and of formal information about natural resources, socio-economic conditions and infrastructure. To address the information problem, the Dept of Science and Technology, Government of India, is developing decision-support systems for decentralized planning using geographical information system (GIS) technology under the Natural Resources Data Management System (NRDMS) program. Its immediate clients are planners and the professional staff of line ministries, in particular the departments of agriculture, forestry, rural development, irrigation and revenue at the district level (all line ministries are represented at the district level).

Since the planning system in India mainly operates in a prescriptive manner (interventions in the shape of development schemes and these may be targeted in the light of a formal zoning of the land according to its capability and suitability) and a top-down / executive-level approach, this Web-based decision support system (DSS) is aimed at district/sub-district level officers who are supposed to make land use plans and take appropriate actions.

1.1 What Decisions are to be Supported?

A DSS can only be successful if in the first instance it supports the existing decision-making process. The DSS is accepted if it assists the decision makers to do their job more accurately and more easily. Subsequent to this level of acceptance, the DSS can introduce new ways to view the decision-making process. After carrying out the needs assessment (through consultancy and workshops with the user community to establish their requirements for plans/actions), the following important classes of conservation planning decision which represents the overall conservation management issues in the Indian Sub Tropical region :

a. Area selection for watershed management schemes
b. Land evaluation for changes in land use

c. Site selection for infrastructure development

The current regulatory framework for watershed-based conservation planning is furnished in Table 2.

Table 2: Broad structure of watershed planning in Indian districts

1.0 Area Selection for Schemes
- 1.1 Which are priority watersheds for intervention by various line Departments
- 1.2 Within priority watershed, which sub-watershed should be treated first
- 1.2.1 Where, within a sub-watershed, are the most critical sectors for different types of intervention

2.0 Site Selection for Interventions
- 2.1 Where should small-scale conservation infrastructure be built by the Government
- 2.2 Where should water resources infrastructure be built or authorized

3.0 Land Evaluation for Changes in Land Use
- 3.1 Where is a particular conservation measure for the existing land use types (LUT) appropriate
- 3.2 Where is a specific management package appropriate for existing LUT
- 3.3 Where should new LUT be recommended and where should infrastructure be placed to facilitate these new LUTs

1.2 How are Decisions Actually Made?

The DSS may not at first address all of the above decisions, as listed in Table 2. We selected the first two decisions (selection of watersheds and land evaluation) on priority basis, after discussions with user community during the present study.

Each scheme is bounded by government policies which have social, economic and biophysical dimensions. Policy is enshrined in the directives that establish the scheme and these commonly lay down criteria for site selection. For example, the National Watershed Development Project for Rainfed Areas (NWDPRA) lays down four criteria: <30 % area is irrigated; <750 mm average rainfall; no other schemes have been implemented; size of a watershed for this scheme is about 10,000 hectares. But site selection according to these criteria is not so straightforward as it might appear. The physical criteria actually reflect the political intension to benefit the disadvantaged. Also, the concept of a watershed is not strictly hydrological; there are no standard maps of watersheds and interestingly, sometimes, they are only delineated once they are identified.

Also, the concept of a watershed is not strictly hydrological; there are no standard maps of watersheds or any standard method for delineating them.

Within any watershed there will be some 20 sub-watersheds, each of 500 hectares, that may be considered the primary planning units because they are small enough for concerted intervention. They must be ranked in order of priority for intervention and, in the absence of the DSS, local staff will recommend sub-watersheds - starting from the highest point – preferring those with a range of land types, and those with the most severe physical and social problems, so that many departments can be involved.

The task of land evaluation for changes in land use is complex. Field workers decide on the desired land use based on on-site inspection. They are recommended based on local needs / socio-economic conditions. These may not always be correct. The farmers decide some of the minor changes in land use, after observing their own experience or their neighbours'. A problem is that farmers may not evaluate correctly whether their field is similar enough to that of their neighbours. Some factors, such as availability of water, surface texture and colour, and crop history are obvious. Changing to a new land utilization type is a radical one in management, especially for poor and risk adverse farmers. It must be introduced with appropriate support. Prior risk assessment is necessary and management practices should be designed to counter the risks.

1.3 The Stand-alone Tool and the Need for National-level DSS

An executive-level PC-based spatial decision support system for rural land use planning (SDSS/LUP) has already been developed under a joint program between the Natural Resources Data Management System (NRDMS) of the Indian Government's Department of Science and Technology and the UN Development Program to assist rural development decision-makers at a district/sub-district level to identify priority watershed sites for different mandated schemes, site selection for infrastructure, and land evaluation for changes in land use (Adinarayana et al., 2000). SDSS/LUP was developed with active involvement of stakeholders at every significant stage of the project: informed-opinions on watershed/conservation management and decentralized planning, maps, reports, etc. This stand-alone SDSS addresses a single district only and is not sufficiently robust for the entire agricultural extension community in the country to use for decision-making.

Hence, it was proposed to extend this agricultural extension activity in geo-spatial technology to a wider community so that a more efficient and affordable way to handle spatial data on the Internet could be developed for conservation planning. A Web based tool would be easier to support in the field than a PC-based system, and Internet connections are now increasingly available to the district level decision-makers who we are targeted as potential users. The WebLUP provides advantages over the desktop SDSS/LUP: the application is centrally located, simplifying distribution and maintenance; and it increases the user base by reducing costs of access to users and data. Recently, an Internet-based SDSS was developed for rangeland watershed management at the University of Arizona (Miller et al., 2003).
The proposed DSS, tentatively called "Web based DSS for rural land use planning – WebLUP", and is intended to assist district officers in their day-to-day land use planning decisions, such as selection of watersheds for various mandated schemes, by displaying maps, and making useful queries to aid decisions. WebLUP is also intended to provide the district staff with hazard warnings for land use sustainability by combining data from existing sources.

2. WebLUP PROTOTYPE DEVELOPMENT

It is proposed to involve district officers in the design of the tool to ensure that it meets their needs. Because users generally have difficulty envisaging new software systems, an iterative development approach is appropriate. A Web based mock-up of the proposed DSS has been developed using HTML image maps. The mock-up covers a very limited range of districts, but users can navigate through it, gaining a feel for what the final system would offer. The mock-up will be shown to decision-makers / potential users and their feedback collected. The mock-up will let users evaluate the proposed system design before investing in further software development resources in a working version.

The basic structure and elements of WebLUP is presented in Figure 1.

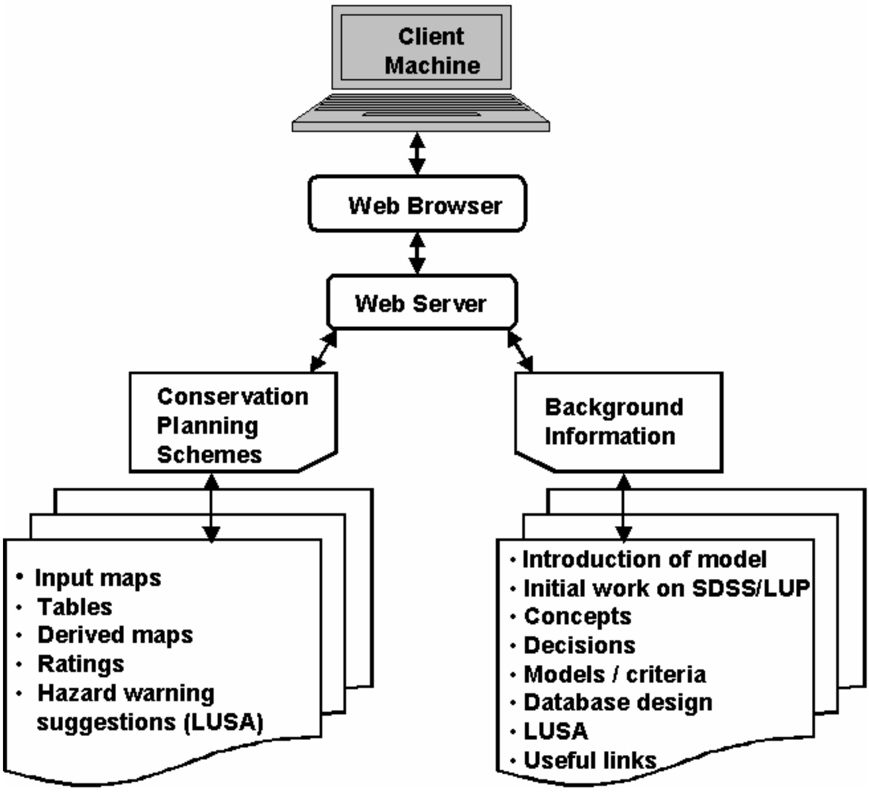


Figure 1 : Basic structure and elements of prototype WebLUP

2.1 Area Selection for Schemes

A brief introduction to the SDSS/LUP work and its various facets are provided in the background component of the WebLUP mock-up. Information, criteria and government efforts on various mandated government-sponsored watershed based schemes have been linked to enable users to select the desired scheme (http://www.csre.iitb.ac.in/adi/dummy-webpage/choosescheme.htm) (Figure 2). Provision is also made to navigate and select the desired district/block in India for watershed management schemes. The mock-up also covers basic natural resources information: watersheds, soils, land use/cover pattern. Given that all watershed informatics are now spatially part of a common coordinated system, a number of useful combinations can be performed. The first step in this process is to create Biophysical Land Units (BPLU). Each BPLU comprises the spatial and non-spatial resource data, and can be taken as a strategic unit for assessing various decisions. Since these units exhibit strong uniformity, they can all be expected to respond similarly to given intensities of human use and management strategies. Use of strategic units for treatment-oriented land use planning schemes for hilly watershed/terrain using GIS has been demonstrated in the studies carried out by Adinarayana and Rama Krishna (1995). Presently, the prototype shows the above basic natural resources information to the users in the form of static maps. In addition, the BPLU map is also linked to the table with ecological and socio-economic dimensions of the watershed in the mock-up.

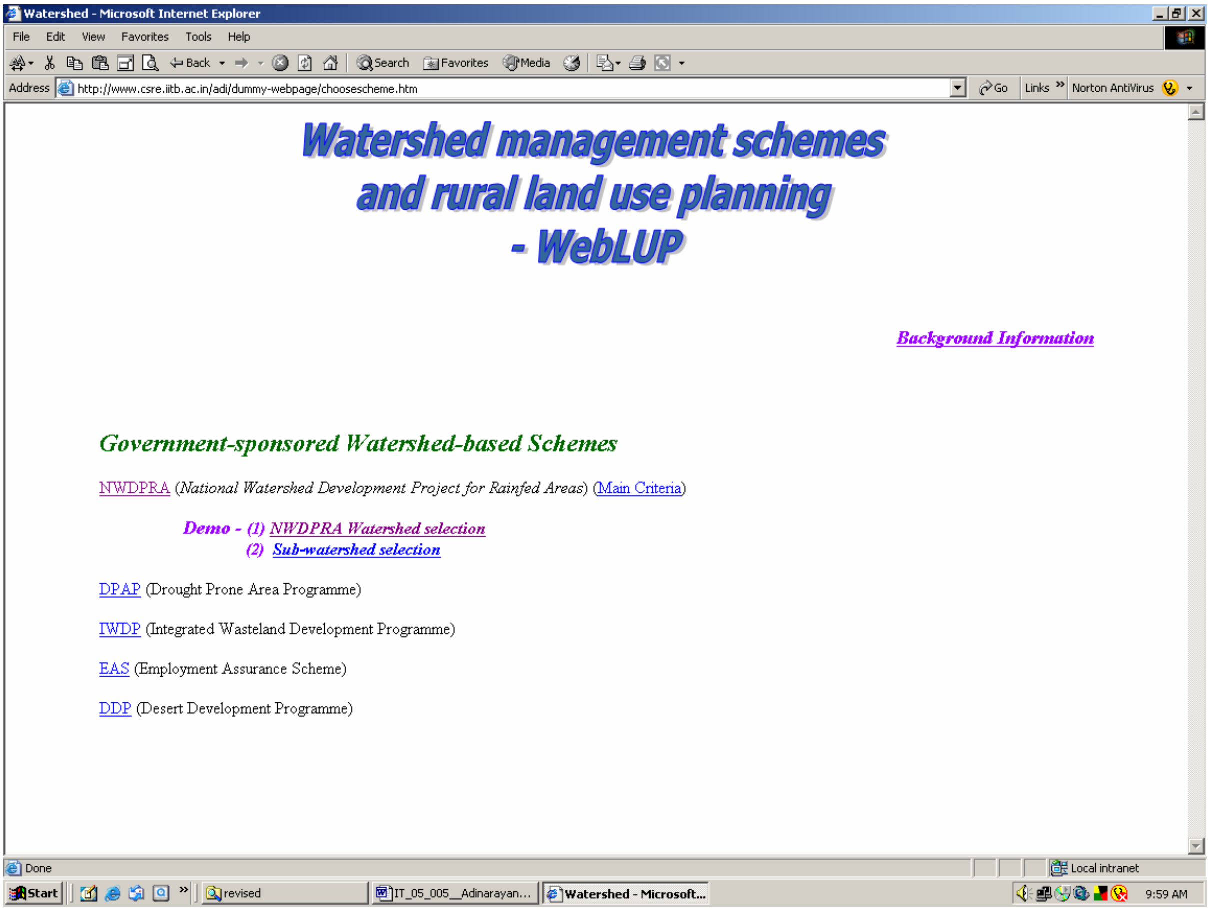


Figure 2. Screen-shot of WebLUP: Home page showing links for Background information, various watershed management schemes and demonstration of NWDPRA watershed, sub-watershed selection

One such central government-sponsored scheme is the NWDPRA (National Watershed Development Project for Rainfed Areas), which is intended to assist with the implementation of conservation planning programmes. The mock-up lets users in Kolar district of Karnataka state to select critical watersheds for the NWDPRA scheme based on physical and socio-economic dimensions (http://www.csre.iitb.ac.in/adi/dummy-webpage/choose-scheme/table.htm) (Priority ratings are in the table with 1 being the highest and 4 being the least) (Figure 3). The mock-up provides three ways to identify priority sub-watersheds (a recommended manageable spatial unit of about 500 hectares) (http://www.csre.iitb.ac.in/adi/dummy-webpage/watershed-scenarios/watersheds.htm) within one of the NWDPRA watersheds on the basis of :

- on-site effects (actual problems with productivity due to erosion or other degradation processes) (Morgan, *et. al*., 1984);

- off-site effects (Actual sediment delivery to reservoirs) (AIS&LUS, 1991); and
- spatial extent and severity of degraded land (through remote sensing technology).

These conservation management scenarios will advise the user which sub-sites should be considered for further under different schemes within the large NWDPRA watershed. For example, the scenario on actual extent and severity of degraded lands, which is one of the serious environmental problems in semi-arid tracts of India, assists the users to identify the sites for a ‘ravine reclamation scheme’ for rehabilitation. A separate single criteria procedure is required for each scheme selection, and then a multi-criteria procedure can also be used to combine them, based on all of the above three ways of identifying critical watersheds, for overall development of these rural watersheds. Or, decision-makers may simply compare several results by eye and use subjective criteria to combine them.

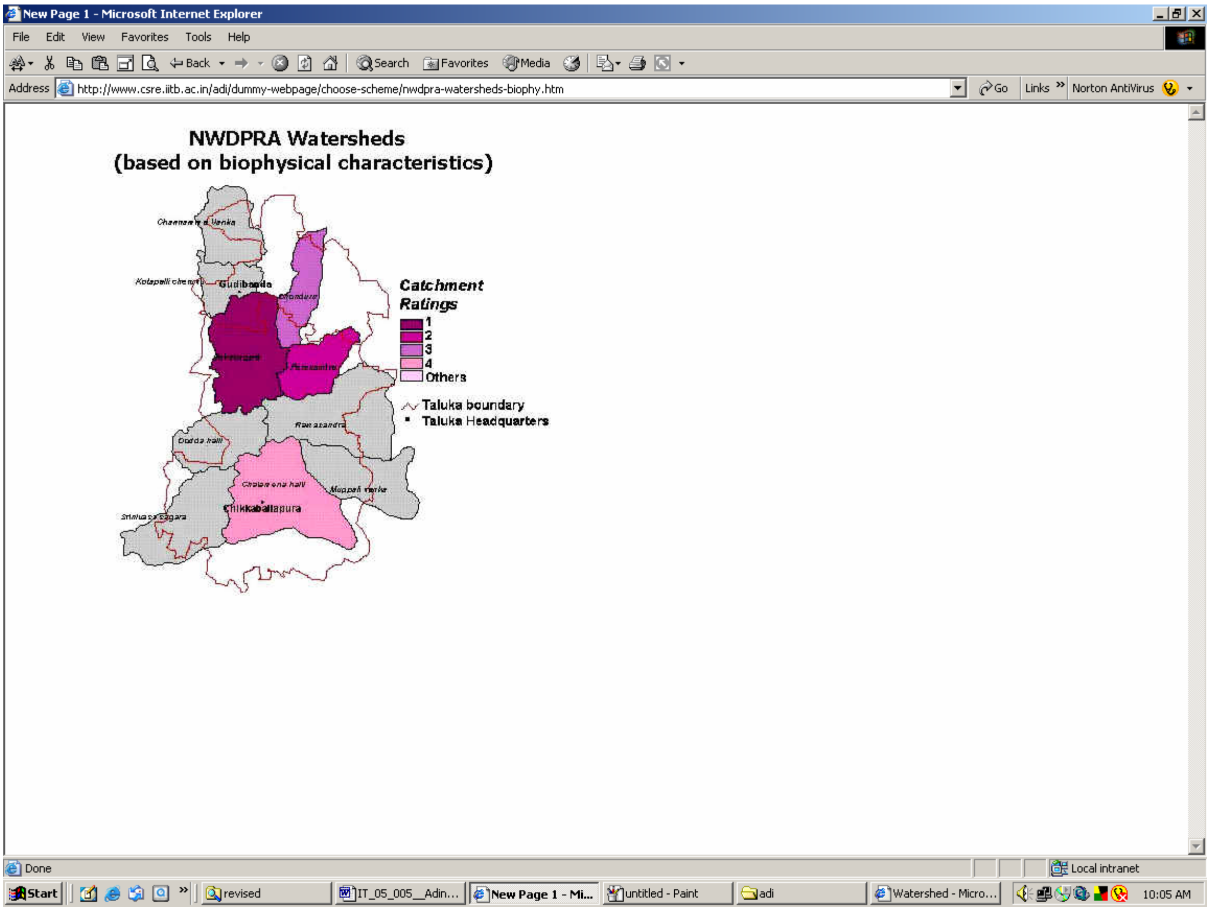


Figure 3. Screen-shot of WebLUP: Prioritisation of NWDPRA watersheds based on biophysical characteristics

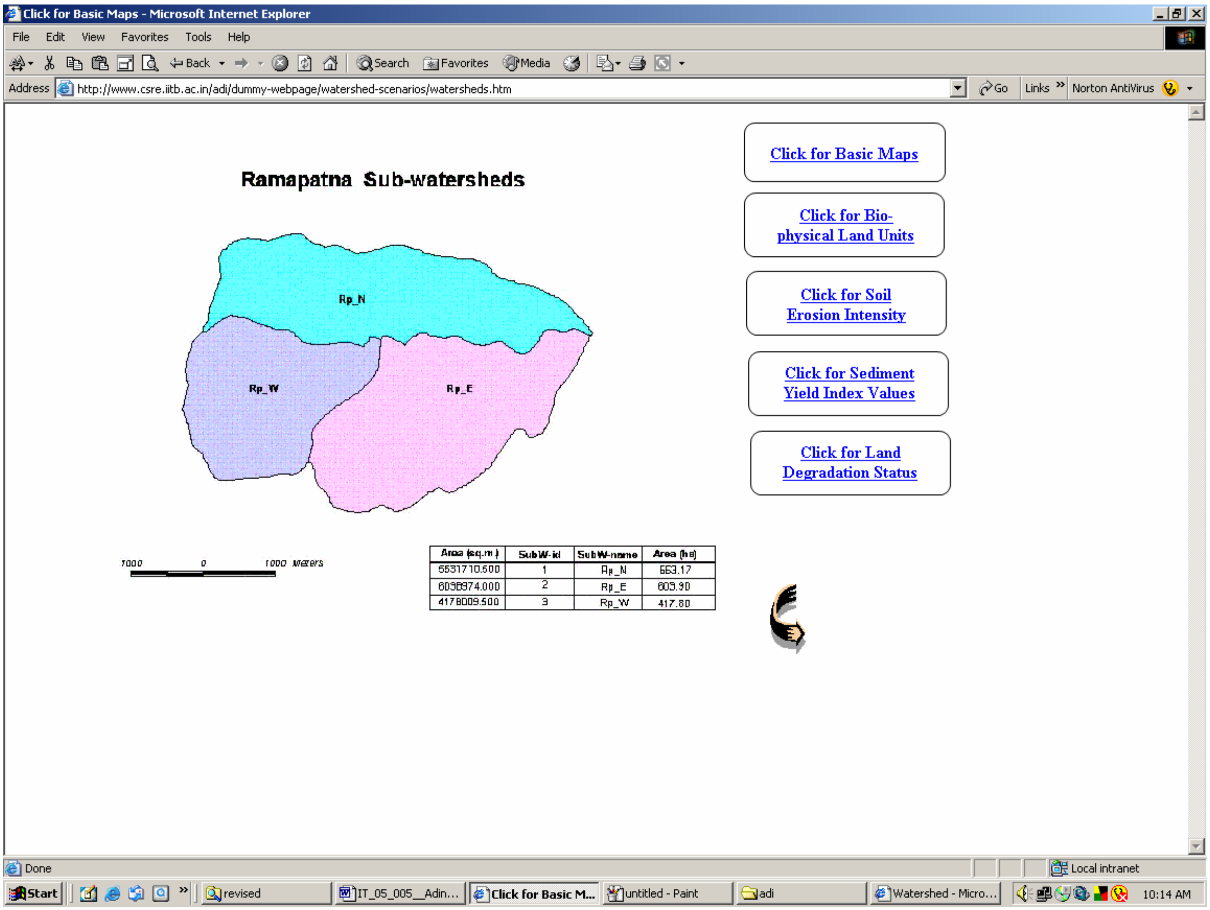


Figure 4. Screen-shot of WebLUP: Links to various sub-watershed scenarios

2.2 Land Evaluation for Changes in Land Use

Land evaluation may be defined as the assessment of land performance when the land is used for specified purposes (FAO, 1985) or, more broadly, as matching land use with land according to their compatibility (Dent and Young, 1981). Once the qualities of the land and the requirements of a land use type are determined, allocation of land use to land or introduction of new management practices can proceed on a rational basis, at least with respect to what the land is capable of supporting.

This is a more complex task than those dealt with so far. It is possible to collect detailed site-specific attributes for special study areas, but this effort cannot be undertaken nationwide. Nevertheless, a National DSS has to provide a consistent level of information and analysis based on data that are available now, nationwide. At present, options are limited by the availability and scale of fundamental data (Table 3).

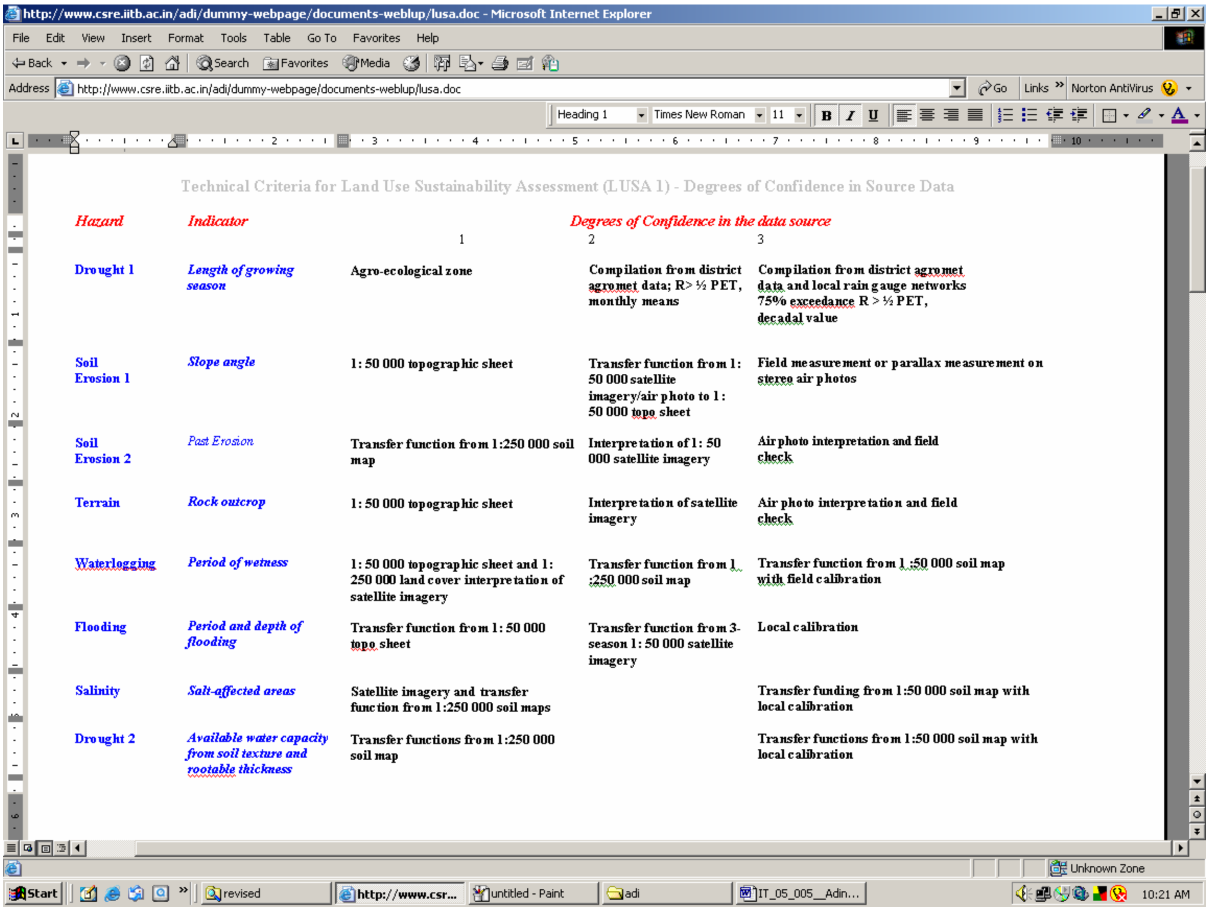
Table 3: Fundamental data availability in the Indian districts

- Digital 1:50 000 scale Survey of India topographic maps, contour interval 20m
- An overlay of district and block boundaries with village centres identified as points
- Social, economic and agricultural census data (*e.g*. proportion of irrigated land)

held in tabular format by administrative unit

- Agro-climatic data, held in tabular format by point. There is an India Meteorological Department station in each district and a much more intensive network of rainfall stations. At a more generalized level, the country has been divided into agro-ecological zones that are matched with crop requirements.
- Geological Survey and, sometimes, geomorphological maps at 1:250 000
- Land cover interpretation of 1:250 000 satellite imagery
- All India Soil Survey maps at 1:250 000, sometimes at 1:100 000
- Nation wide Census of India data of 1991 in digital form by the National Informatics Centre (NIC). Latest 2001 Census data is available in some pockets from the NIC.
- Census GIS – an interactive thematic census data (of 2001) on demographic details online for district and state level

The problem of inadequate data is being handled by a rough land use sustainability assessment (LUSA) using existing data (Adinarayana et al., 2000). LUSA provides spatial information on various threats/hazards in support of conservation planning and the sustainability of different land use types (Figure 5). With this information, users can design management packages to combat the threats/hazards to the sustainability of the desired land use, or receive recommendations for an alternative land use. In short, we are applying the threat identification and management (TIM) concept outlined by Smith *et. al.*, 1999.


Technical Criteria for Land Use Sustainability Assessment (LUSA 1) - Degrees of Confidence in Source Data

Hazard	Indicator	Degrees of Confidence in the data source: 1	2	3
Drought 1	*Length of growing season*	Agro-ecological zone	Compilation from district agromet data; R> ½ PET, monthly means	Compilation from district agromet data and local rain gauge networks 75% exceedance R > ½ PET, decadal value
Soil Erosion 1	*Slope angle*	1: 50 000 topographic sheet	Transfer function from 1: 50 000 satellite imagery/air photo to 1 : 50 000 topo sheet	Field measurement or parallax measurement on stereo air photos
Soil Erosion 2	*Past Erosion*	Transfer function from 1:250 000 soil map	Interpretation of 1: 50 000 satellite imagery	Air photo interpretation and field check
Terrain	*Rock outcrop*	1: 50 000 topographic sheet	Interpretation of satellite imagery	Air photo interpretation and field check
Waterlogging	*Period of wetness*	1: 50 000 topographic sheet and 1: 250 000 land cover interpretation of satellite imagery	Transfer function from 1 :250 000 soil map	Transfer function from 1 :50 000 soil map with field calibration
Flooding	*Period and depth of flooding*	Transfer function from 1: 50 000 topo sheet	Transfer function from 3-season 1: 50 000 satellite imagery	Local calibration
Salinity	*Salt-affected areas*	Satellite imagery and transfer function from 1:250 000 soil maps		Transfer funding from 1:50 000 soil map with local calibration
Drought 2	*Available water capacity from soil texture and rootable thickness*	Transfer functions from 1:250 000 soil map		Transfer functions from 1:50 000 soil map with local calibration

Figure 5. Screen-shot: Part of LUSA framework

WebLUP mock-up/prototype, including the LUSA format, is presently available for the policy makers and rural land use managers at http://www.csre.iitb.ac.in/adi/projects/projects-ongoing.html. The mock-up is being tested for validation and modification. It might be argued that this approach excludes the actual land users; simply perpetuating the traditional top-down planning ideology. But it should result in better-informed district-level staff who can bring new perspectives to their ongoing interaction with land users. The decision-support service that can be provided as of now meets the requirements specified during the needs assessment. As far as land evaluation is concerned, it is unsophisticated but it is robust and functions with the data that are actually available in every district in India.

3. FUTURE / RESULTING SYSTEM

The mock-up attracted a large user community and initial discussions with them encouraged the investigating team to consider the following development objectives to create an improved system.

3.1 Dynamic/Interactive System

High bandwidth, reliable Internet connectivity, and carefully prepared underlying data will be keys to the future success of the proposed Web based decision support tool.

To allow the dynamic and interactive mapping/queries that are expected, WebLUP will use, Web components of an indigenously developed low cost Windows based GIS package, called GRAM++ (Venkatachalam and Krishna Mohan, 2000). It should make the resulting system available through the Internet to the district level users. It is expected that additional tools, such as demographic and socio-economic analyses, will be added to expand the applicability of the data for end users in their other day-to-day rural development decisions. Once operational and acquainted with GRAM++, the system/database would be regularly updated by the users.

The basic structure of an enhance WebLUP is illustrated in Figure 6.

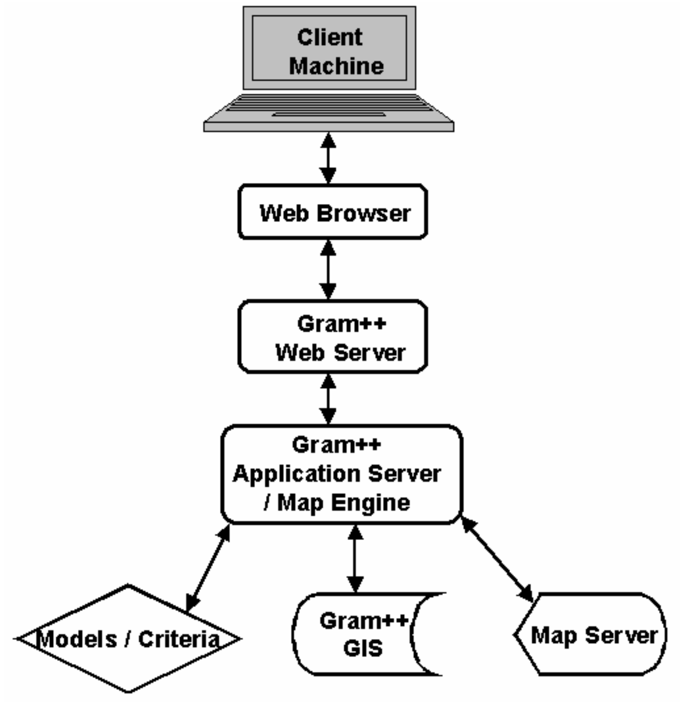


Figure 6: Future WebLUP architecture

3.2 Inclusion of Socio-economic Dimensions in the System

This Web based tool will complement rural extension work by providing meaningful, practical and methodological information on conservation and land use management. This will be a valuable tool for extension agents in disseminating information and will allow them to point their clients in the right direction and clarify problems, and also to solve soil/water conservation problems a more integrated and practical on-the-ground (and participatory/inclusive) approach would be more appropriate. However, the socio-economic and marketing components of watershed conservation and management also need to be considered in order to provide more comprehensive, productive and profitable alternatives to the users. In this regard, to provide a better service with a better database, a cut-down version of ALES (Automated Land Evaluation System) (Rossiter and Van Wambeke, 1997) can be added to the resulting system to provide a framework for land suitability evaluation for specific crops/land use types, including a basic financial/economic analysis.

3.3 Transfer Functions

The problem of inadequate data can also be handled, alternatively, by developing transfer-functions to derive a single attribute data required by LUSA. For the usual case in which the existing mapping is not at the required scale, or shows only compound mapping units (*e.g.* soil associations), models can be developed to predict the attributes of interest from the available digital elevation model held within the GIS. This is done for each soil landscape by establishing the relationships between each attribute of interest and the position in the landscape and slope form. However, developing and automated approach of developing and implementing these transfer functions is a complex problem.

4. CONCLUSIONS

A national level WebLUP mock-up is developed from an existing stand-alone SDSS/LUP to assist the rural extension community in the Indian districts in their own existing decision making processes.

It is hoped that simple, low cost, project oriented, easily maintained and user-friendly tools like WebLUP has the best chance of success in extending the existing land use policy to the ICT (Information and Communication Technology) / Web oriented land use policy amongst the novice land use managers in the districts. It is also hoped to attract feedback and initial interest from other academic/land use planners, and provide the opportunity for those with similar ventures to make contact with each other within India and abroad.

The resulting WebLUP model is an attempt to shift the technology from 'Laboratory to Land' and from 'Doers to Users' to solve a few open solutions in conservation planning.

5. ACKNOWLEDGEMENTS

The work was carried out in the Department of Information Science & Technology, NARC/NARO, Japan under the auspices of the Invitation Fellowship Programme of Japan Society for the Promotion of Science (JSPS). The senior author (JA) wish to acknowledge the consultancy services provided in the UNDP/DST Project (IND/95/002) by Dr David Rossiter of the ITC-Enschede, The Netherlands, and Dr David Dent of the ISRIC-Wageningen, The Netherlands, which served as valuable insights in the mock-up.

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